FAST ORBIT FEEDBACK SYSTEM UPGRADE IN THE TLS

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Abstract

Orbit feedback system of the 1.5 GeV Taiwan Light Source (TLS) has been deployed for a decade. The loop bandwidth was limited by existing hardware. The system cannot remove orbit excursion caused by the perturbation due to fast operation of insertion devices. To improve orbit feedback performance, corrector power supply and BPM system are undergoing upgraded. New digital BPM electronics will enhance functionality of the BPM system as well. It is expected that the upgrade will significantly improve performance of the orbit stability. New fast orbit feedback system is designed to achieve a submicron stability of the electron beam working at a bandwidth of at least 60 Hz.

INTRODUCTION

The Libera Electron/Brilliance [1] is employed to replace the existing BPM electronics to improve orbit measure performance and provide better functionality of BPM system in TLS. The group topology of Libera Electron/Brilliance to acquire fast data at 10 kHz rate is summarized. Progress of the corrector power supply upgrade is also addressed. Infrastructure of the new orbit feedback system is implemented gradually without interrupt of the routine operation of the TLS. Effects of the PID parameters on system response and noise attenuation are demonstrated both by simulations and experiments. Diagnostic functions by using 10 kHz rate will be also setup along with the new orbit feedback system. Current diagnostics is based upon 10 Hz data in control database and therefore transient response and spike can't be analyzed precisely. A dedicated diagnostic node which stores data at higher sampling rate and has hardware and software trigger is planned to build. The possibility of Advanced Telecom Computing Architecture (aTCA) for future upgrade of TLS fast orbit feedback system will be discussed in the last. It can also be a test bed of orbit feedback system for the newly proposed 3 GeV Taiwan Photon Source (TPS) applications.

STATUS OF CURRENT ORBIT FEDBACK SYSTEM

The current orbit feedback system was deployed in ten years ago. The existing corrector power supplies are intended to reduce loop bandwidth to eliminate high frequency noise that causes problem in the spectrum of Fourier transform infrared spectroscopy in the infrared beamline. Therefore, the orbit feedback system cannot be operated at full bandwidth. To accommodate fast operation of various insertion devices and provide better orbit stability, the old BPM electronics and corrector power supplies are replaced step by step. Figure 1 shows the beam position reading during the phase change of EPU5.6 undulator with and without orbit feedback response at the R1BPM0 and R1BPM8 which are equipped with Libera Electron. Orbit perturbation due to EPU5.6 is rather suppressed by feedback system while high speed operation of the insertion devices is still restrained by low closed loop bandwidth of the orbit feedback system. The orbit stability shall be further improved after the system upgrade in 2008.

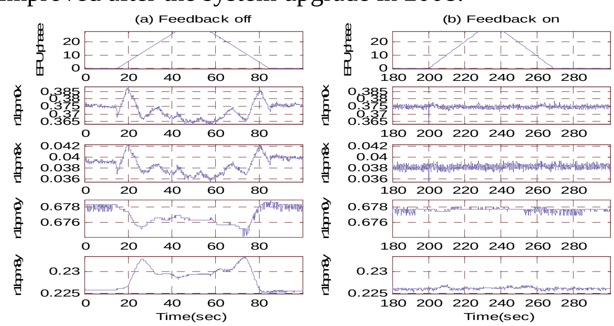

Figure 1: Effectiveness of the orbit feedback loop versus phase change of the EPU5.6 undulator. (a) without feedback; (b) with feedback

BPM AND CORRECTOR POWER SUPPLY UPGRADE

Libera Electron/Brilliance's integration had rise from 2007. The migration is gradually deployed not to interfere with the routine operation. To reduce GbE jitter and achieve better performance, numbers of Libera Electrons/Brilliances are grouped together to produce a packed GbE UDP packet to reduce the number of IP packets. Since the TLS has six super-periods, it is decided that all Libera Electron/Brilliance of one or two super-period will be grouped together. The vertical corrector power supply is already replaced by MCOR 30 [2] in the January of 2007. Standard deviation of the vertical power supplies (vertical corrector) and horizontal power supplies (horizontal corrector) in 100 sec readings are shown in Fig. 2. Performance of the new MCOR power supply is better than the old one. The new power supply current readings of the vertical corrector power supply have the around 0.5 mA standard deviation since it is limited by the 16 bit ADC module. New power supply performance is expected at least 4 times better. Power supplies performance can be better than 16 bits. Each MCOR crate can be equipped 8 MCOR 30 power supply modules to save space. The horizontal corrector power supply is planned to be replaced during the shutdown in mid-2008. Bandwidth determined by a whole of power supply, corrector and the vacuum chamber is increased from a few Hz to 100 Hz and 30 Hz in vertical and horizontal respectively.

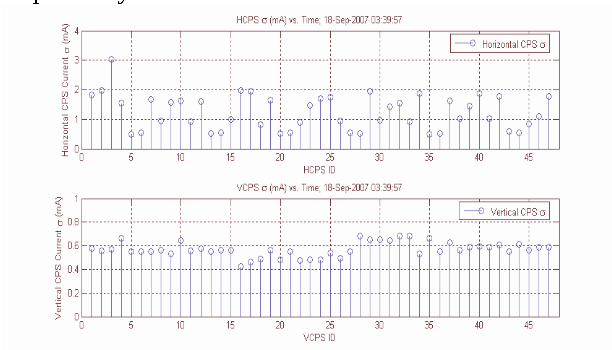

Figure 2: Power supply performance of the old power supply and the MCOR 30 power supply.

UPGRADE FAST ORBIT FEEDBACK INFRASTRUCTURE

The infrastructure of the new orbit feedback system is upgraded from the original system without change too much and enables a gradually upgrade without interfere the routine operation [3], as shown in Fig. 3. The reflective memory is employed to shares fast orbit data without consuming extra CPU resource. This approach will keep for the new fast orbit feedback system. The orbit data will be acquired by several VME G4 PowerPC CPU modules equipped with two GbE ports. The orbit data will be shared by the reflective memory mounted to the 5 VME nodes for beam position acquisition, feedback engine and the diagnostics node. After the migration completed, higher sampling rate (5 KHz or 10 kHz will be determined according the computing power of existed CPU module) is planned rather than the current 1 kHz sampling rate.

Noticeable jitter will introduce if 10 kHz rate UPD packages transmitted by many Liberas (>5, increase as number of Linera Electron) and processed by a G4 PowerPC CPU module running LunxOS. This may degrade performance of feedback system and even lead to instability. The Libera group which packs numbers of Liberas payload data into a single UDP packet to reduce the GbE traffic is therefore concluded and its operation is being in implementation phase. It is planned that each PowerPC CPU will receive an UDP package from a group of Libera Electron/Brilliance to eliminate the problem of processing jitter.

Since there are no dedicated fast correctors at TLS, setting of the DC closed orbit control and the fast correction signal will sum in an analogue way. It will be implemented by an in-house made interface card mounted to the leftmost slot of MCOR crate which adds the setting command and feedback correction setting to the power modules. Since the switching power supplies will replace all of the current linear power supplies in 2008, we expect the integration will be accomplished in the meanwhile. New corrector power supply combined with magnet and vacuum provide an about 100 Hz and 30 Hz open loop bandwidth in vertical and horizontal plane respectively. Closed loop bandwidth can achieve 100 Hz in vertical plane without problem. To achieve more than 60 Hz or higher bandwidth in horizontal plane, a compensator is in study.

Capture fast orbit data for 10 seconds are valuable to the orbit performance monitoring, system modelling and post mortem analysis for some unexpected events. A diagnostics node will be setup for this purpose. The captured data will be analysis in Matlab environment. Hardware and software trigger mechanism with pre-post transient recorder will support. Combined with post mortem buffer for turn-by-turn data inside the Libera Electron/Brilliance and data captured by this diagnostic node might be very useful for clarifying various reasons of beam trip, this is essential to improve system reliability.

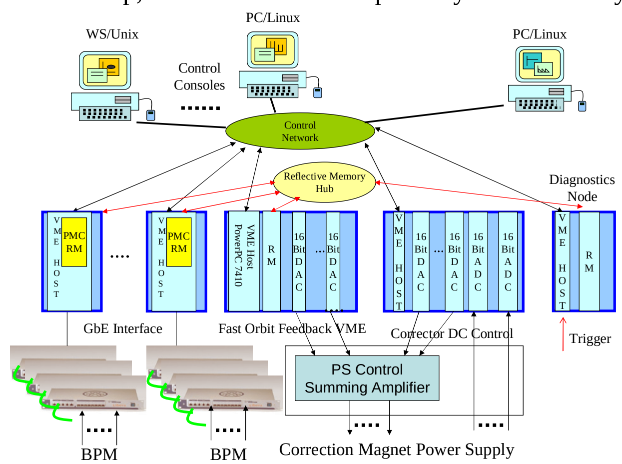

Figure 3: Infrastructure of the new fast orbit feedback system.

CURRENT ORBIT PERFORMACE STUDY

A small number of Libera Electrons is already installed to accompany with the existing BPM system in seamless way to examine its short-term and long-term stability and operation reliability. Numbers of Libera Electron (~ 30 sets) for half of the ring is standby in the lab. A remaining half of the BPM electron which will be the new Libera Brilliance is still in procurement and expected ready in early 2008. Libera group operation will be tested before the end of 2007. The infrastructure of the orbit feedback system is already settled.

Various effects are studied thoroughly during a period of migration. Figure 4 shows the perturbed beam position due to field leakage of the injection septum. How to eliminate the unwanted perturbation is in study. The beam excursion is large in the horizontal plane. This excursion cannot be effectively removed by the feedback due to the limited bandwidth of the horizontal even if the orbit feedback system upgraded. So, a gating signal will pause the excursion of the feedback algorithm during the injection. Typical injection will sustain several shoots in 100 msec repetition rate during typical top-up injection scenario. Beam motion with strong line frequency components are also observed by the fast orbit data as

Figure 5. These are expected to be removed after new fast orbit feedback system deployed in 2008.

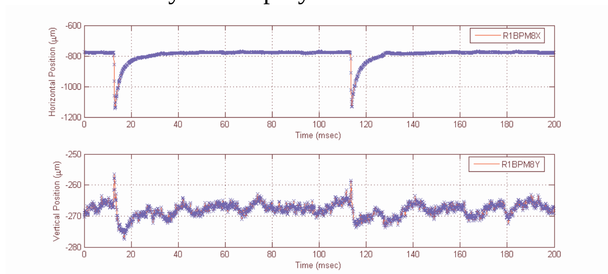

Figure 4: Perturbed beam position due to field leakage of the injection septum.

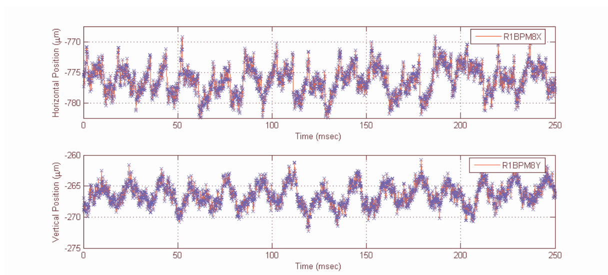

Figure 5: Strong line frequency components appear at the measured beam position.

SIMULATION ANALYSIS

To study various effects on the performance of the feedback system, Matlab scripts were developed. Functional block diagram of the simulation scripts is shown in Fig. 6. We can analyze that different BPMs have respective characteristic against disturbance, frequency response of the feedback loop, and optimum PID parameters.

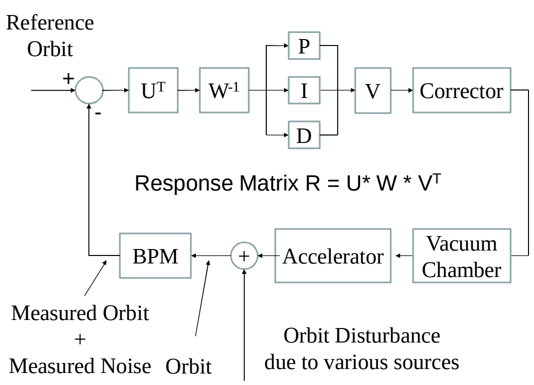

Figure 6: Feedback block diagram.

Removing small singular value is adopted to avoid unnecessary large correction value. The PID coefficients setting are therefore according to different eigenvector. Correct modes with small singular value would have less weighting and not be corrected as more as other modes.

PLANNED FUTURE ACTIVITIES

Increasing the control resolution of corrector power supplies is under study. It is a possible upgrade option in the future. Possibility to adopt the aTCA architecture for a future upgrade of TLS is under investigation. This structure is also proposed for the newly proposed 3 GEV TPS. Combined features of high throughput communication and high performance computing capabilities in the aTCA crate seems to be a promising solution in the future fast orbit feedback. The proposed structure is shown in Fig. 7. How to synchronize the operation of a feedback system with many components which are communicated with fast serial links requires further investigation. If this upgrade is possible in the future, it is not only for the orbit feedback system of the TLS, but also can be used for the testbed for TPS. All functionalities can be tested at real machine.

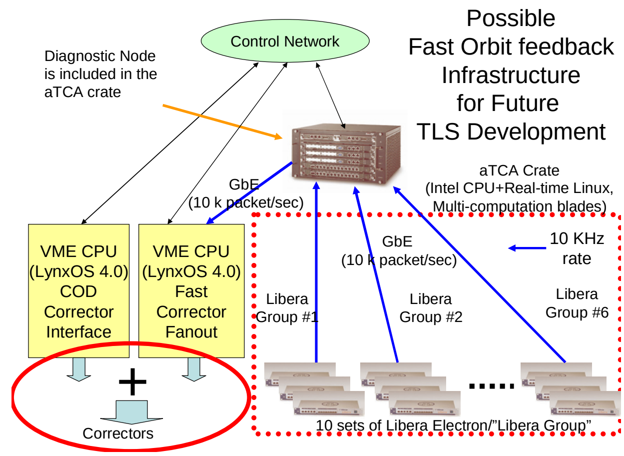

Figure 7: Architecture of the proposed orbit feedback system for further upgrade for TLS.

SUMMARY

Design and status of the new fast orbit feedback system of the TLS at the NSRRC are summarized in this report. Migrate to new BPM electronics and new corrector power supply is planned to be completed in mid-2008. Infrastructure is continuously modified and emerged. Better performance is expected to cope with fast source and make fast operation of insertion devices possible.

REFERENCES

[1] http://www.i-tech.si.
[2] http://www.bira.com/.
[3] C.H. Kuo, et al., “Integration of the Digital BPM in the Taiwan Light Source”, Proceedings of ICALEPSC 2005, Geneva, Switzerland.